LabWrite improving lab reports

CoursePak for standard labs—Lab experiments driven by hypotheses

Description: The following documents provide you with a packet of all core LabWrite materials you can print or use in PDF format. Note that the Resources page included here only contains a list of LabWrite Resources. If you want a particular resource, you'll have to go to the Resources homepage and print it.

LabWrite improving lab reports

SelfGuide

Printable Version

PreLab: questions to answer before doing the lab

First, carefully read the description of the lab:

In most lab classes, you will have a lab manual that contains background for the lab and directions for doing the lab procedure. There may also be handouts or other materials you have access to. Read it all. And don't just skim it. In fact, you may need to read it more than once to get a good grasp of it.

Next, answer the following questions about the lab:

1. What scientific concept(s) is this lab about?

Identify the scientific concept(s) (principle, theory, law) of the lab and write what you know about the concept(s) from the lab manual, textbook, class notes, handouts, etc.

> Most science labs are designed to help you learn about a scientific concept. If you are having trouble identifying the scientific concept this lab is about, check the title of the lab in the lab manual and read the introduction to the lab in the manual. It will be something like photosynthesis, chemical reactions, or inertia. Write down the scientific concept.
>
> Then write down what you know about the concept based on the lab manual, textbook, class notes, and handouts. Don't try to make it pretty; just write it. Get as much down as you can. Because the point of the lab is to learn about the scientific concept, it's important to state what you already know about it.

2. What are the objectives for this lab?

Describe the specific actions you are being asked to perform in the lab, such as measure something, analyze something, test something, etc.

> Objectives are the activities you are being asked to do in order to complete the lab experiment. Often the objectives are listed in the lab manual. You can list the objectives or write them in a paragraph. If they are not listed in the lab manual, read the lab procedure and figure out from the procedure what the objectives of the lab are. Because objectives are activities, be sure to list them as such: to measure, to analyze, to determine something.

3. What is the overall purpose of the lab?

Briefly describe how what you are being asked to do in the lab (the objectives) will help you learn about the lab's scientific concept(s). In other words, show the link between your response to question #2 (what you will do in the lab) to your response to question #1 (what you are supposed to be learning about by doing the lab).

> The purpose of the lab is to learn something about the scientific concept the lab is about. This is where you make the all-important link between what you are doing and what you are learning. For example, if the scientific concept is photosynthesis, how will measuring respiration rates help you understand photosynthesis? This is the kind of question you need to ask yourself. Read over the objectives again. They outline what you will be doing

in the lab experiment. Describe how you think completing the lab will help you learn about the concept?

4. What is your hypothesis for the lab experiment?

First, identify the **variables** in the experiment. Then state your **hypothesis**--the relationship or interaction among the variables, the outcome of the experiment you anticipate. Your hypothesis may be stated in 1-2 sentences or sketched out as a graph. (See below for definitions of underlined terms.)

> The variables are what you will manipulate (independent variable) and measure (dependent variable) in the lab procedure. The hypothesis is what you anticipate will be the outcome of the procedure, typically the resulsts of the measurements of the dependent variables when the independent variable(s) is manipulated. So the hypothesis is what you expect, based on your understanding of the scientific concept of the lab--what the relationship among the variables will be.

Variables:

A **variable** is what is measured or manipulated in an experiment. Variables provide the means by which scientists structure their observations. Identifying the variables in an experiment provides a solid understanding of the experiment and what the key findings in the experiment are going to be.

To identify the variables, read the lab procedure described in the lab manual. Determine what you will be measuring and what you will be manipulating for each measurement. The value(s) you are manipulating is called the **independent variable** (see definition below) and the value(s) you are observing/recording is called the **dependent variable** (see definition below). Write down the dependent and independent variables. In more advanced labs, you may have **multiple variables** (see definition below), more than one independent and dependent variable.

Independent and Dependent Variables:
An **independent variable** is the variable you have control over, what you can choose and manipulate. It is usually what you think will affect the dependent variable. In some cases, you may not be able to manipulate the independent variable. It may be something that is already there and is fixed, something you would like to evaluate with respect to how it affects something else, the dependent variable like color, kind, time.

A **dependent variable** is what you measure in the experiment and what is affected during the experiment. The dependent variable responds to the independent variable. It is called dependent because it "depends" on the independent variable. In a scientific experiment, you cannot have a dependent variable without an independent variable.

Example 1: You are interested in how stress affects heart rate in humans. Your independent variable would be the stress and the dependent variable would be the heart rate. You can directly manipulate stress levels in your human subjects and measure how those stress levels change heart rate.

Multiple Variables:
It is possible to have experiments in which you have **multiple variables**. There may be more than one dependent variable and/or independent variable. This is especially true if you are conducting an experiment with multiple stages or sets of procedures. In these experiments, there may be more than one set of measurements with different variables.

Example 2: You are interested in finding out which color, type, and smell of flowers are preferred by butterflies for pollination. You randomly choose an area you know to be inhabited by butterflies and note all the species of flowers in that area. You want to measure pollination of flowers by butterflies, so your dependent variable is pollination by butterflies. The independent variables are flower color, type, and smell. You will need to specify relationships for each of these independent variables with the dependent variable.

Hypothesis:

A **hypothesis** is a scientist's best estimation, based on scientific knowledge and assumptions, of the results of an experiment. It usually describes the anticipated relationship among variables in an experiment. Since dependent variables "depend" on independent variables, there has to be a relationship between the two. The anticipated relationship between the dependent and independent variables is the result you expect when one variable reacts with another.
A hypothesis typically leads to the crucial questions that must be addressed in the lab report: did you find what you expected to find? why or why not? The point of an experiment is to test the hypothesis. Write or sketch your hypothesis, describing the relationship among the variables you listed.

5. What reasoning did you use to arrive at your hypothesis?

Explain your hypothesis using the scientific concept of this lab to show the reasoning behind your prediction.

Your hypothesis is a prediction of the outcome of the lab. This prediction is based on your understanding of the scientific concept of the lab. That understanding shapes your prediction of how the lab experiment will turn out, the relationship among variables that you anticipate. Write a paragraph or so describing the logic you used to go from your understanding of the scientific concept to formulating a prediction of the outcomes of the experimental procedure.

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NC STATE UNIVERSITY

Name: ____
Date: ____
Lab Section: ___________________________________
Lab Title: _____________________________________

PreLab: questions to answer before doing the lab

Note: This is the handout version, which only contains the PreLab questions. For more help or additional information, you'll need to go to the on-line version of PreLab at http://labwrite.ncsu.edu where you can view additional materials on-line or obtain a full printable version under PreLab SelfGuide.

First, carefully read the description of the lab:

In most lab classes, you will have a lab manual that contains background for the lab and directions for doing the lab procedure. There may also be handouts or other materials you have access to. Read it all. And don't just skim it. In fact, you may need to read it more than once to get a good grasp of it.

Next, answer the following questions about the lab:

1. What scientific concept(s) is this lab about?
Identify the scientific concept(s) (principle, theory, law) of the lab and write what you know about the concept(s) from the lab manual, textbook, class notes, handouts, etc.

2. What are the objectives for this lab?
Describe the specific actions you are being asked to perform in the lab, such as measure something, analyze something, test something, etc.

3. What is the overall purpose of the lab?
Briefly describe how what you are being asked to do in the lab (the objectives) will help you learn about the lab's scientific concept(s). In other words, show the link between your response to question #2 (what you will do in the lab) to your response to question #1 (what you are supposed to be learning about by doing the lab).

4. What is your hypothesis for the lab experiment?
First, identify the variables in the experiment. Then state your hypothesis--the relationship or interaction among the variables, the outcome of the experiment you anticipate. Your hypothesis may be stated in 1-2 sentences or sketched out as a graph.

5. What reasoning did you use to arrive at your hypothesis?
Explain your hypothesis using the scientific concept of this lab to show the reasoning behind your prediction.

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Printable Version

InLab: the lab experiment

1. Setting up the lab:

Before you start the lab, review the objectives and procedures you will follow. Take notes as you set up your experiment and calibrate instruments to help you document your experimental protocol so that you may use it later when writing the Methods section of your lab report.

> On a sheet of paper or in your lab manual or in a formal lab notebook, list the lab materials you'll be using and describe the set-up for this experiment. Take notes about potential sources of uncertainty so that you may refer to them when you are writing the Discussion section of your lab report. You may want to or may be required to draw and label the instrument(s) you'll be using.

(See below for definitions of underlined words.)

(Refer to the web version of this document for example lab notebook pages.)

Lab notebook:

Keeping accurate lab notebooks is very important for professional scientists and engineers. Their lab notebooks are permanent legal records of all work conducted in the laboratory. Because of their importance, professional lab notebooks should be:

- Logs or journals of all the information collected during lab, including procedures and sketches of instruments or tools.
- Written in ink with corrections initialed and noted.
- Labeled with page numbers, time, date, and titles for all procedures, tables, charts, graphs, etc.

Sources of Uncertainty:

In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. This is why it is so important to keep detailed notes of everything you do in the lab procedure and any problems you encounter. Try to be especially aware of any problems in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.

For advanced labs, you may want to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random-those that cannot be predicted-or as systematic-those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

2. Getting ready to collect data:

Before you start collecting data, you need to reconsider the whole point of the lab procedure: to determine whether or not your hypothesis is supported by the data from the experiment. Revisiting your hypothesis and gathering information about the data you will be collecting will help you to better understand your data as you are collecting them. It will also help you to organize your data in a table or spreadsheet.

- Review and restate the hypothesis you are testing and the variables involved. This may be a good time to refer to your PreLab. If you haven't completed a PreLab, create a hypothesis now before you start the lab procedure.
- List the variables in the experiment, noting which are independent and which are dependent. Refer to your PreLab if you have completed it.
- Next to each variable, write the units of measurement you will use in the lab. Noting the unit of measurement for each variable will help you to be sure you are recording the data correctly.
- Determine whether or not you have control and treatment groups in this experiment. Determining whether or not your experiment uses control and treatment groups will help you to structure your data so that you can see more clearly the relationship between those two groups.

(See below for definitions of underlined words.)

Hypothesis:

A hypothesis is scientist's best estimation, based on scientific knowledge and assumptions, of the results of an experiment; it describes the relationship between the dependent and independent variables. Since dependent variables "depend" on independent variables, there has to be a relationship between the two. The anticipated relationship between the dependent and independent variables is the result you expect when one variable reacts with another. In science, relationships between variables are usually shown in graphs. The independent variable is plotted along the horizontal or x-axis and the dependent variable along the vertical y-axis.

Variables:

A variable is what is measured or manipulated in an experiment. Variables provide the means by which scientists structure their observations. Identifying the variables in an experiment provides a solid understanding of the experiment and what the key findings in the experiment are going to be.

To identify the variables, read the lab procedure described in the lab manual. Determine what you will be measuring and what you will be manipulating for each measurement. The first of these are the dependent variables and the other is the independent variable (see definitions and examples below). Write down the dependent and independent variables.

A dependent variable is what you measure in the experiment and what is affected during the experiment. The dependent variable responds to the independent variable. It is called dependent because it "depends" on the independent variable. In a scientific experiment, you cannot have a dependent variable without an independent variable.

An independent variable is the variable you have control over, what you can choose and manipulate. It is usually what you think will affect the dependent variable. In some cases, you may not be able to manipulate the independent variable. It may be something that is already there and is fixed, something you would like to evaluate with respect to how it affects something else, the dependent variable.

It is possible to have experiments in which you have multiple variables. There may be more than one dependent variable and/or independent variable. Usually, you choose one independent variable at a time and observe its effect on one or more dependent variables.

Unit of Measurement:

A standard of basic quantity or increment by which something is divided, counted, or described, such as ml, kg, mm, m/s, °F, etc.

Control and Treatment Groups:

A control group is used as a baseline measure. The control group is identical to all other items or subjects that you are examining with the exception that it does not receive the treatment or the experimental manipulation that the treatment group receives. For example, when examining test tubes for catalytic reactions of enzymes when added to a specific substrate, the control test tube would be identical to all other test tubes with the exception of lacking the enzyme. The treatment group is the item or subject that is manipulated. In our example, all other test tubes containing enzyme would be part of the treatment group.

3. Preparing a table or spreadsheet for recording your data:

Using the information you have gathered about the data you will be collecting, create a **raw data table** or **set up a spreadsheet** (refer to the web version of this document to access these resources) for entering your data. (If your lab manual already has a table for the data, skip this step.)

For help in determining which you should create now, a table or a spreadsheet, see below for a comparison of the two. For general information on tables go to "Graphing Resources" in the Resources page on the web version of this document. Choose "Designing Tables."

Creating a Table or a Spreadsheet:

A table provides a very convenient tool for organizing the data you collect in your lab. You can quickly draw a table on a sheet of paper, you can make one with a word processing program, or you can generate one with spreadsheet software. Using a hand-drawn table in the lab also allows you the flexibility of entering the data into a spreadsheet at a later time. The chief advantage to entering data in a spreadsheet is that you can easily convert it not only into a table but also into all sorts of graphs.

Use this guide to figure out whether or not you should use a table or a spreadsheet for recording your data in the lab:

- If you do not have access to a computer with spreadsheet software in your lab, then you should create a table. You can use the data in the table to generate a spreadsheet later, if necessary.
- If you know you will need to create graphs for your data and have access to spreadsheet software in the lab, then use the spreadsheet.
- If you are not sure what form, table or graph, you will be using to report your findings and it is convenient to use a spreadsheet, then use a spreadsheet.
- If creating a spreadsheet in the lab will take too much lab time, then use a table and create the spreadsheet later.

4. Conducting the experiment:

Carefully follow the experimental protocol. As you conduct your experiment and record your data, take notes on what you are doing and on any changes in your procedure. Also, describe in writing or sketch out on a sheet of paper your observations as you collect data during the experiment (observations are potentially significant things that are not reflected in the measurements: color, smell, interesting reactions, unexpected behaviors, etc.) As you record your data, take note of any trends emerging in the data.

Taking good notes will help you recall the experiment later on when you are writing your lab report. It's also important to note any problems with the procedure or deviations from the established protocol. Even if you are following the protocol in a lab manual, sometimes you will set up and run things differently.

As you record your data, you should be asking yourself various questions: What are the relationships among the variables? Do the data behave in the way that you had anticipated? If not, why not? If the data make no sense, you may need to consider sources of uncertainty once again. Sources of uncertainty may affect the accuracy and precision of your experimental data. For more information on statistical calculations and graphical display of uncertainty, see the graphing tutorial on Using Error Bars in Graphs.

(See below for definitions to underlined terms.)

Relationships Among the Variables:

Since dependent variables "depend" on independent variables, there has to be a relationship between the two. The relationships between the dependent and independent variables are what is described in the hypothesis. So it's important to determine what those relationships are in order to see whether or not the hypothesis has been supported.

Sources of Uncertainty:

In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. This is why it is so important to keep detailed notes of everything you do in the lab procedure and any problems you encounter. Try to be especially aware of any problems in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.

For advanced labs, you may want to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random-those that cannot be predicted-or as systematic-those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

Accuracy and Precision:

Accuracy refers to the closeness of a measured value to a standard or known value. For example, if in lab you obtain a weight measurement of 3.2 kg for a given substance, but the actual or known weight is 10 kg, then your measurement is not accurate. In this case, your measurement is not close to the known value.

Precision refers to the closeness of two or more measurements to each other. Using the example above, if you weigh a given substance five times, and get 3.2 kg each time, then your measurement is very precise. Precision is independent of accuracy. You can be very precise but inaccurate, as described above. You can also be accurate but imprecise.

For example, if on average, your measurements for a given substance are close to the known value, but the measurements are far from each other, then you have accuracy without precision.

A good analogy for understanding accuracy and precision is to imagine a basketball player shooting baskets. If the player shoots with accuracy, his aim will always take the ball close to or into the basket. If the player shoots with precision, his aim will always take the ball to the same location which may or may not be close to the basket. A good player will be both accurate and precise by shooting the ball the same way each time and each time making it in the basket.

5. Visualizing the data:

Now that you have entered your data in a table or spreadsheet, you are ready to represent the data in the appropriate visual format for your lab report. Representing your data in a visual format will allow you to identify trends and relationships among variables more easily. Follow these steps:

- Establish what types of data you have, **quantitative or qualitative** (refer to the Resources page in the web version of this document; once there, choose "Data Types").
- Determine if the data should be represented as a **table or a graph** (refer to the Resources page in the web version of this document; once there, choose "Tables vs. Graphs").
- If you decide to use a graph to represent your data, determine which **type of graph** is one that best represents your data (refer to the Resources page in the web version of this document; once there, choose "Graph Types").
- If a table is the best format for your data, then modify the table you used to collect your data so that it is labeled and organized properly (refer to the Resources page in the web version of this document; once there, choose "Designing Tables").
- If you need help creating a spreadsheet to make a table or graph, refer to the Resources page in the web version of this document. Once there, choose "Excel Tutorial".
- Remember that the purpose of your table or graph is to summarize your findings for yourself and for others and to reveal trends in your data.

6. Making sense of your data:

Review all your data--tables, graphs, and drawings--and try to make sense of the overall findings of the lab procedure. Summarize the overall findings in a sentence or two. If your lab instructor says it is permissible, compare your findings with those of other students in the lab.

Summarizing your data in a sentence or two helps you to understand the lab. It is also useful for when you write the Results section of your lab report.

Corroborating data or sharing findings is a very common practice among scientists, which usually leads to more ideas and experimentation. For this reason, comparing your results to other students' results can be valuable as a way of testing your findings. It's OK if your findings are different. Your job is to try to figure out why, to identify the sources of the difference. You can use this information when explaining your findings in the Discussion section of your lab report.

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InLAB Handout

Name: ______________________________________

Date: _______________________________________

Lab Section: _________________________________

Lab Title: ____________________________________

InLab: Steps to follow while you are completing your lab experiment

Note: This is the handout version, which only contains the InLab steps. For more help or additional information, you'll need to go to the on-line version of InLab at: http://labwrite.ncsu.edu

1. Setting up the lab:

Before you start the lab, review the objectives and procedures you will follow. In the space below, list the materials you'll be using and describe the set-up for this experiment including instrument calibrations. Take notes about potential sources of uncertainty so that you may refer to them when you are writing the Discussion section of your lab report. You may want to or may be required to draw and label the instruments you'll be using. Use the back of this sheet, if necessary.

2. Getting ready to collect data:

List all the variables in the experiment, identifying independent variable(s) and dependent variable(s). Beside each variable, give the unit of measurement, where appropriate. State your hypothesis, your prediction of the relationship or interaction among variables (revise your original one if necessary). It may be stated in 1-2 sentences or sketched out as a graph.

3. Preparing a table or spreadsheet for recording your data:

Use the list of variables and units of measurement to create a table or set up a spreadsheet for entering your data. You can use the space below to sketch out a table. If necessary, you can put more tables on the back of this sheet. If your lab manual already has tables for reporting your data, use it instead.

4. Conducting the experiment:
Carefully follow the experimental protocol. As you conduct your experiment and record your data, take notes in the space below on what you are doing, being sure to note any changes from the protocol. Describe or sketch other observations as you collect data during the experiment. As you record your data, make notes about trends that emerge in the data.

5. Visualizing the data:
Now that you have entered your data in a table or spreadsheet, you are ready to represent your data in the appropriate visual format for your lab report.

- Establish what types of data you have, quantitative or qualitative (refer to the Resources page in the web version of this document; once there, choose "Data Types").
- Determine if the data should be represented as a table or a graph (refer to the Resources page in the web version of this document; once there, choose "Tables vs. Graphs").
- If you decide to use a graph to represent your data, determine which type of graph is one that best represents your data (refer to the Resources page in the web version of this document; once there, choose "Graph Types").
- If a table is the best format for your data, then modify the table you used to collect your data so that it is labeled and organized properly (refer to the Resources page in the web version of this document; once there, choose "Designing Tables").
- If you need help creating a spreadsheet to make a table or graph, refer to the Resources page in the web version of this document. Once there, choose "Excel Tutorial."
- Remember that the purpose of your table or graph is to summarize your findings for yourself and for others and to reveal trends in your data.

6. Making sense of your data:
Review all your data--tables, graphs, and drawings--and try to make sense of the overall findings of the lab procedure. Summarize the overall findings in a sentence or two. If your lab instructor says it is permissible, compare your findings with those of other students in the lab. Take notes here of what you found, and if there are any differences in the findings, write down some possible reasons for the differences.

PostLab: writing your lab report

The following pages include the PostLab guide for writing your lab report. A good strategy is to open a word processing file and write the report following the directions step by step. Follow the LabWrite process, beginning with writing Methods and finishing with writing the title. Then when you've finished, you can rearrange the sections of your report in the proper order for turning it in.

SelfGuide

SECTION ONE : Methods

Describing the lab procedure

Using your lab manual, handouts, and notes taken during the lab as a guide, describe in paragraph form the experimental procedure you followed. Be sure to include enough detail about the materials and methods you used so that someone else could repeat your procedure.

The Methods section is a concise chronological description of the laboratory procedure you used in the lab. It's important to remember that even though the teacher who reads your lab report already knows the lab procedure, you should write it as if he or she did not. The point is to demonstrate that you have a solid grasp of the procedure you followed. Describing it clearly and in detail allows the teacher to see that you understand the procedure.

- Begin by reviewing the directions in the lab manual and any notes you took as you did the lab. If it is a complex procedure, make a rough outline of what you did.
- Write the procedure in paragraph form. For relatively simple labs, one paragraph will do; more complex labs will take multiple paragraphs. Keep the paragraphs relatively short because it's hard for readers to process detailed information like this without sufficient breaks.
- Describe what you actually did in your own experiment, even though it may be somewhat different from the ideal procedure in the manual. The Methods section should be an accurate reflection of what you did.
- Avoid putting any results of the lab in the Methods. Just describe what you did, not what you found.
- Use the proper past tense and passive voice. Methods are usually written in past tense because you are describing what you have already done. They are also typically written in passive voice ("Two ml. *were pipetted* into a test tube"). However, your lab instructor may permit you to use active voice, which uses first person, "I" or"we" ("We *pipetted* 2 ml. of the solution into the test tube").

More Helpful Hints:

- To make your description of the experimental procedure clear, use appropriate transitional or "sign post" words that indicate a sequence and help the reader follow the sequence: step 1, step 2, step 3; first, then, finally; first, second, third; after, next, later, following; etc.
- Include the methods you used for both gathering data and analyzing the data.

For more advanced labs:

- If your lab is complicated, perhaps consisting of more than one experimental procedure, then consider dividing your Methods into sections with subheadings.
- If you used what is considered a standard procedure (one that competent scientists in the field are likely to be familiar with) then there is no need to describe it in detail. Simply state that you used that procedure, being sure to give its common name. (If you are not sure about what standard procedures are in your field, ask your lab instructor.)
- When describing an apparatus or instrument, it's better to include a sketch of it rather than to try to describe it fully in words. This is especially useful in cases where the apparatus is complex or designed by you. All you need is a couple of

sentences that give a general sense of the apparatus, and then refer the reader to the figure that contains the sketch, the same way you would refer the reader to tables or graphs.

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SECTION TWO : Results

Making sense of your data for yourself and others

Step 1: If you haven't already done so, put your lab data in visual form by creating appropriate tables, graphs, and other figures. Representing your data in a visual format will allow you to identify trends and relationships among variables more easily.

More Help:

- Establish what types of data you have, quantitative or qualitative (refer to the Resources page in the web version of this document; once there, choose "Data Types")
- Determine if the data should be represented as a table or a graph (refer to the Resources page in the web version of this document; once there, choose "Tables vs. Graphs").
- If you decide to use a graph to represent your data, determine which type of graph is one that best represents your data (refer to the Resources page in the web version of this document; once there, choose "Graph Types").
- If a table is the best format for your data, then modify the table you used to collect your data so that it is labeled and organized properly (refer to the Resources page in the web version of this document; once there, choose "Designing Tables"). .
- If you need help creating a spreadsheet to make a table or graph, refer to the Resources page in the web version of this document. Once there, choose "Excel Tutorial."

Step 2: Once you have generated visual representations of your data, decide the order in which your tables, graphs, or other figures should be presented in the Results section.

More Help:

The visuals tell the main story of your data, so you need to decide how to organize visuals so that they tell the story most effectively. Deciding what order to put your visuals in is more of an issue in complex labs with multiple data sets, and may not be an issue in simple labs. If you have been told what visuals to include in your report and the order to put them in, go to Step 3 of Results.

Three ways of organizing your visuals:

- chronological order: if the lab consists of more than one procedure, you can present the results in the order in which you did the procedures, especially if that order provides a useful way of leading the reader through the results.
- order of importance: arrange the visuals by putting the one that is the most important first and then the others in descending order of importance.
- order of generality: sometimes it is better to start with the most general representation of the data and then place the more specific ones after that, especially if the specific ones serve to support the broad representation or add more details to it.

Step 3: Review all the data from your experiment. In a sentence or two, summarize the main finding of this lab. This is the opening sentence(s) of the Results section.

More Help:

Summarizing your overall results in a sentence or two allows you to make sense of the findings of the lab for yourself and for your reader. A one- to two-sentence summary allows the lab instructor to judge how well you understand the lab as a whole.

- Review the findings in your visuals (tables and graphs and other figures). If you have trouble shaping a one-sentence summary, look for a unifying feature among the data sets. This is likely to be the dependent variable. The sentence will be a general statement that summarizes your findings about that variable or related variables.
- You can start the sentence in several ways: "The results of the lab show that …"; "The data from the experiments demonstrate that…"; "The independent variable X increased as Y and Z were…."

Step 4: In separate paragraphs, summarize the finding in each of your visuals--tables, graphs, or other figures. First state the overall relationship or interaction among variables that each visual represents. Then include any specific details from the visual that are important for understanding the results. Refer to your tables, graphs, or other figures as figure or table 1, 2, 3, etc.

More Help:

The main job of the Results section is to report data from the lab. The Results typically consists of both visual representations of data (tables and graphs and other figures) and written descriptions of the data.

- Describe each visual in a separate paragraph. Each paragraph has two parts:
    1. The first sentence gives the general finding (see below for definition) for the visual, what it indicates overall, and
    2. The following sentence(s) provides key details from the visual that are important to understanding the experiment (don't include all the details).

General Finding:

You can determine the general finding for each visual in one of two different ways:

1. as a summary of all the information in the visual **OR**
2. as a statement that focuses on the most important point that is made in the visual (important, that is, in terms of the hypothesis).

- Refer to your visual(s) in the written part of your Results in one of two ways:
    1. Refer to your visual(s) at the beginning of your findings, for example, "Table 1 shows that the reaction times decreased as the strength of the solution increased." "Figure 3 demonstrates that the mortality rate among riparian mammals adhered to approximately seven-year cycles." (It is also possible to use verbs such as "lists," "displays," "describes," etc.)
    2. Refer to your visual(s) in parentheses at the end of the of your findings. For example, "The reaction times decreased as the strength of the solution increased (Table 1)." "The mortality rate among riparian mammals adhered to approximately seven-year cycles (see Figure 3)." (Ask your teacher which format to use for parenthetical documentation.)

Step 5: Complete the Results by placing all the elements you've written in the proper order: (1) the sentence summarizing the overall data for the lab; (2) the paragraphs of word descriptions for each visual arranged in the order the visuals are presented.

The Results looks like this:

- Summary of overall findings of lab
- Paragraph related to visual 1
    1. Sentence of overall finding from visual 1
    2. Sentence(s) with key details from the visual 1
- Paragraph related to visual 2
    1. Sentence of overall finding from visual 2
    2. Sentence(s) with key details from the visual 2
- Paragraph related to visual 3
    1. Sentence of overall finding from visual 3
    2. Sentence(s) with key details from visual 3, etc.

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SECTION THREE : Introduction

Establishing a context for the lab

Step 1: Revise your answer to PreLab question 1 in one or two paragraphs. Begin the Introduction with 1 or 2 sentences clearly stating what scientific concept the lab is about. Then use the rest of your answer to question 1 to complete the paragraph with information about the scientific concept. Revise your answer so that it includes only the information that relates specifically to this lab. If your have a lot of information, make two paragraphs. Note any citations you use here for including in the References section of your report.

More Help:

- If you are having trouble writing a good opening sentence for the lab report, you can say something like: "This laboratory experiment focuses on X…"; "This laboratory experiment is about X…" ; "This lab is designed to help students learn about, observe, or investigate, X…." Or begin with a definition of the scientific concept: "X is a theory that…."
- Once you have your opening sentence, you are ready to complete the opening paragraph by telling what you know about the scientific concept. The point is to show your lab instructor that you have a good grasp of the scientific concept. Revise the rest of Question 1 by:
  Focusing it so that it contains information about the concept that is most clearly related to the lab procedure (not everything there is to know about the concept)
  Incorporating additional relevant information about the concept you may have learned since doing the PreLab.
  Changing it so that the scientific concept is appropriate to the lab (this would apply if all or parts of what you wrote about the scientific concept in the PreLab are wrong for this lab).
- If you have a lot to say about the scientific concept, use more than one paragraph.
- This part of the Introduction is typically written in present tense.

For more advanced labs:

If you are writing a lab report that is more like a full scientific paper, you may need to do more research using the Internet and library. With your teacher's guidance, you should search the recent scientific literature to find other research in this area of study. Summarize that research in a paragraph or so, stating what the general findings have been and using those findings to describe the current knowledge in the area (such a "review of the literature" is typical of scientific journal articles). This summary should come after your initial sentence about the scientific concept. For help with citing references, go to Citations and References in the Resources Page of the on-line version of this document.

Step 2: Revise your answers to PreLab questions 2 and 3. Write the main objectives of the lab in sentence form. Then complete the paragraph by describing how the achievement of these objectives helped you learn about the scientific concept of the lab.

More Help:

- If your response to Question 2 was a list of objectives, revise it by summarizing the primary objectives in your own words. The point is to demonstrate your understanding of what you were supposed to do in the lab. With most labs, you should be able to do this in 1 or 2 sentences. You can begin by saying something like: "The main objectives of this lab were to…"; "In this lab we were asked to …." This will be the beginning of the paragraph.

- Continue the paragraph by revising your answer to question 3, showing that you comprehend the purpose of the lab. Revise your answer by making it clear how accomplishing the objectives of the lab helped you to learn about the scientific concept of the lab. You can start by saying something like this: "The objectives of this lab enabled me to learn about X by…"; "Performing these objectives helped me to understand X by…."
- This part of the Introduction is usually all in past tense.
- If you have redefined the scientific concept of the lab since the PreLab, revise your answer to question 3 accordingly.

Step 3: Revise your answers to PreLab questions 4 and 5 in a paragraph or two. First, state your hypothesis clearly (even if it was not supported by the data). Then rewrite the explanation for your hypothesis so that your reader understands how the reasoning behind your hypothesis is based on the scientific concept of the lab.

More Help:

- Revise your original hypothesis from PreLab question 4 so that it is clear that it is a hypothesis: "The hypothesis for this lab was…"; "My hypothesis was…"; "We predicted that…"; "I hypothesized that…."
- Finish the paragraph by revising your response to PreLab question 5, explaining how you came to your hypothesis. As you are explaining the reasoning you used to come to your hypothesis, be sure to make a direct connection between the hypothesis and the scientific concept of the lab. Rewrite it so that your reader can clearly see how you used your understanding of the scientific concept of the lab to make a prediction about the outcome of the lab. Refer to what you said in the first paragraph of the Introduction.
- One way to make your explanation clear is to use words that show causal links: *because*, *since*, *due to the fact that*, *as a result*, *therefore*, *consequently*, etc. For example, Since X happens in order to maximize energy, we hypothesized that . . .
- If your explanation is relatively long, use more than one paragraph.

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SECTION FOUR : Discussion

Interpreting the results of the lab

Step 1: Write a sentence or two stating whether or not the results from the lab procedure fully support your hypothesis, do not support the hypothesis, or support the hypothesis but with certain exceptions.

More Help:

Experimental science is all about testing hypotheses. Thus, the statement of whether or not your hypothesis has been supported is critically important to the lab report. It is by no means a failure if your data do not support your hypothesis; in fact, that can be more interesting than the other way around, because you may find a new perspective for looking at the data. Failure to support hypotheses is common in science, and often serves as a starting point for new experiments.

- Go back to the statement of hypothesis in the Introduction. Then review your findings, the data from the experiment. Make a judgment about whether or not the hypothesis has been supported. It is at this point that you, as a scientist, must be as unbiased and objective as possible.
- Write a statement stating your judgment. There are three possible judgments you can make:
    1. the data support the hypothesis;
    2. the data do not support the hypothesis; or
    3. the data generally support the hypothesis but with certain exceptions (tell what those exceptions are).

Example: "The hypothesis that X solution would increase in viscosity when solutions Y and Z were added was supported by the data."

Step 2: In a paragraph, identify specific data from your lab that led you to either support or reject your hypothesis. Refer to the visual representations of your data as evidence to back up your judgment about the hypothesis.

More Help:

It is important to back up the statement about the hypothesis with direct evidence from the lab data that support, do not support, or partially support the hypothesis.

- Return to the Results to identify the particular data that led you to your judgment about the hypothesis.
- Write a paragraph (or 2 if necessary) in which you present the relevant pieces of data from the lab and show how they relate to the hypothesis.
- Refer to data from specific visuals appropriately: Table 1, Figure 2, etc.

Step 3: In a paragraph, use your understanding of the scientific concept of this lab to explain why the results did or did not support your hypothesis. If the hypothesis from the Introduction was not fully supported, show how your understanding of the scientific concept has changed. Note any citations you use here for including in the Reference section of your report.

More Help:

In Step 2 you pointed to data that led you to your judgment about your hypothesis. Now you use your understanding of the scientific concept of the lab to explain your judgment.

Whatever the relationship between the hypothesis and the results, you must provide a logical, scientific basis for it.

- Return to the scientific reasoning you used to generate your hypothesis (at the end of the Introduction). Use it and your understanding of the scientific concept of the lab as starting points for your explanation. Your explanation is likely to follow one of four scenarios. Choose the one that best fits your report:
    - If the results fully support your hypothesis and your reasoning in the Introduction were basically sound, then elaborate on your reasoning by showing how the science behind the experiment provides an explanation for the results.
    - If the results fully support your hypothesis but your reasoning in Introduction was not completely sound, then explain why the initial reasoning was not correct and provide a better reasoning.
    - If the results generally support the hypothesis but in a limited way, then describe those limitations (if you have not already done so) and use your reasoning as a basis for discussing why those limitations exist.
    - If the results do not support your hypothesis, then explain why not; consider (1) problems with your understanding of the lab's scientific concept; (2) problems with your reasoning, and/or (3) problems with the laboratory procedure itself (if there are problems of reliability with the lab data or if you made any changes in the lab procedure, discuss these in detail, showing specifically how they could have affected the results and how the uncertainties could have been eliminated).

Step 4: Discuss other items as appropriate, such as (1) any problems that occurred or sources of uncertainty (see below for definition of underlined word) in your lab procedure that may account for any unexpected results; (2) how your findings compare to the findings of other students in the lab and an explanation for any differences; (3) suggestions for improving the lab.

Sources of Uncertainty:

In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. This is why it is so important to keep detailed notes of everything you do in the lab procedure and any problems you encounter. Try to be especially aware of any problems in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.

More Help:

After dealing with the critical issue of the hypothesis, the rest of the Discussion may consider other issues. You can address these in separate paragraphs.

- Return to the notes you took during the lab procedure. Look for possible sources of uncertainty in setting up the lab, calibrating instruments, and taking measurements as well as problems with materials you are using.
- In scientific articles, the Discussion is where scientists typically compare their results to those from other scientific experiments. You can do something similar by comparing your results to those of other students in the lab. In your paragraph, comment on any similarities or differences you find and offer possible explanations for the differences. Be sure to check with the lab instructor to see if it is permissible to compare results.
- Professors who write lab manuals are typically interested in how they can improve the experiments in the manuals. You can also demonstrate your ability to provide productive critique of the lab by offering suggestions for improvement.

For advanced labs:

- It may be useful to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random--those that cannot be predicted--or as systematic--those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

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SECTION FIVE : Conclusion

Focusing on what you learned by doing the lab

Step 1: Write a paragraph summarizing what you have learned about the scientific concept of the lab from doing the lab. Back up your statement with details from your lab experience.

More Help:

The Conclusion is where you make it clear to the lab instructor what you learned in the lab experience. Since the purpose of the lab is to learn something about science, take the time to write a Conclusion that convinces the lab instructor of what you have learned.

- Return to the scientific concept you established in the Introduction. But instead of describing what you know about the scientific concept in the Conclusion, describe what you learned about the concept from doing the lab. For example:
  - How has your understanding of the concept improved or otherwise changed from doing the lab?
  - What specific aspects of the procedure or data contributed to your learning?
  - What difficulties did you have with the concept before doing the lab and how were those difficulties alleviated by doing the lab?
  - How might what you have learned in the lab be applicable in the future?
- Be direct in your statement of what you have learned. Don't be afraid to start out saying, "In this lab, I learned that ...." This sort of clarity will be appreciated by the reader. Elaborate on your statement with additional details about what you have learned.

Step 2: If there is anything else you have learned about from doing the lab, such as the lab procedures or kinds of analyses you used, describe it in a paragraph or 2.

More Help:

- There may be more that you have learned about from the lab experience than the scientific concept of the lab. If so, write a paragraph describing it. For example:
  - Was there anything in the lab procedure that you found particularly interesting to learn how to do?
  - Did you apply a procedure for analyzing data that was useful to learn about?
  - Did you learn anything about using a spreadsheet or graphing or creating other visuals?
  - Did you learn anything about writing or about science from writing the report?

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SECTION SIX : Abstract

Summarizing the lab report

Summarize each major section of the lab report--Introduction, Methods, Results, Discussion, and Conclusion--in 1 sentence each (two if a section is complex). Then string the summaries together in a block paragraph in the order the sections come in the final report.

More Help:

You can think of the Abstract as a miniature version of the whole lab report. Read each section of the report and boil it down to a sentence. This means that you need to determine the most important information in each section.

- Here are some suggestions for what to include in each sentence of the Abstract:
  Introduction: main objective(s) of the lab; hypothesis
  Methods: a quick description of the procedure
  Results: statement of the overall findings
  Discussion: judgment about hypothesis; explanation for judgment
  Conclusion: what you learned about the scientific concept
- Put all these sentences together into one paragraph with the heading "Abstract."

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SECTION SEVEN : Title

Capturing the essence of the report

Write a title that captures what is important about the lab, including the scientific concept the lab is about and variables involved, the procedure, or anything else that is important to understanding what this report is about.

More Help:

You write the title after you have written the other parts of the report, because the title reduces the report down to its essence, and it's not until you finish writing the report that you are able to identify what that essence is. A good title very efficiently tells the reader what the report is about.

Hints:

- If you are having trouble writing a title, try this approach. List the keywords related to the report: the scientific concept of the lab, the kind of procedure you used, names of key materials, what you experimented on, etc. Then write a title that describes the lab using the most important of these keywords.
- A title should use the fewest possible words to adequately describe the content of the report.
- A title should be as specific as possible. Specify the primary focus of the experiment and procedures used, including the scientific names of chemicals, animals, etc.
- Do not write the title as a complete sentence, with a subject and a verb. Titles are labels, not sentences.
- Do not use catchy titles. This is not an English paper or an editorial.
- Find the right balance for the length of the title: not so short that it doesn't communicate what the report is about but not so long that it rambles on for more than a line.

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SECTION EIGHT : References

Acknowledging sources of information

If it is appropriate for your lab report, put a References section at the end. List all the sources you referred to in writing the report, such as the lab manual, a textbook, a course packet, or scientific articles. Be sure to use the proper form of documentation for the scientific field you are working in (ask your lab instructor if you are not sure). See Citations and References in the Resources Page of the web version of this document.

More Help:

- Different scientific fields use somewhat different styles for documenting sources in the References. For example, in chemistry you would follow the American Chemical Society (ACS) style. In biology, it would be the Council of Biological Editors (CBE) style. Check to see which style is appropriate for your class.
- You can find information about various documentation styles at Citations and References in the Resources Page of the web version of this document.

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LabChecklist : SelfGuide

The Title of my Lab Report...

- ☐ describes the specific content of the lab concisely but with enough detail to get the main ideas across to the reader.

The Abstract of my Lab Report...

- ☐ summarizes the gist of each section of the report in a sentence (or two for an especially complex section).
- ☐ arranges the sentences in the order the sections are presented in the report, Introduction to Conclusion.
- ☐ stays within the maximum words allowed (usually 100-200 words, but if there is a different word limit for your class, be sure you are within it).

The Introduction in my Lab Report...

- ☐ starts out by stating (in a sentence or two) the scientific concept the lab is about and then describes what I know about that scientific concept that is relevant to the lab (typically one or two paragraphs).
- ☐ sets down in sentence form the main lab objective(s) and then describes what these objectives will help me learn about the scientific concept of the lab (typically one paragraph).
- ☐ states the hypothesis and then explains how I arrived at the hypothesis, using what I know about the scientific concept of the lab as the basis for my reasoning (typically one or two paragraphs).

The Methods in my Lab Report...

- ☐ provides a concise, easy-to-follow description of the specific procedures followed in the lab.
- ☐ gives enough detail of both the materials and the procedure used so that the experiment could be repeated just as I did it.

The Results in my Lab Report...

- ☐ begins with a sentence or two describing the overall findings of the lab.
- ☐ contains visuals (tables or graphs or other figures) that are appropriate to the data and are arranged in an order that best tells the "story" of the data.
- ☐ consists of a paragraph for each visual and structures each paragraph by (1) summarizing in a sentence or two the overall trend shown in that visual and then (2) supporting the summary by including any specific details from the visual that are important for understanding the results.
- ☐ clearly refers to the appropriate visuals in the paragraphs (Table 1, Figure 2, etc.).
- ☐ reports the data from the experiment only, successfully avoiding any explanations or conclusions about the data.

The Discussion in my Lab Report...

- ☐ begins with a statement of whether or not the overall results support, do not support, or support to some extent my original hypothesis (in the Introduction).
- ☐ points to specific data from the findings as evidence for deciding whether or not the hypothesis is supported

- ☐ uses what I have learned about the scientific concept of the lab to explain in a convincing way why or why not the data support my hypothesis.
- ☐ addresses other issues that may be appropriate, such as (1) any problems that occurred or sources of uncertainty in the lab procedure; (2) how the findings compare to the findings of other students in the lab and an explanation for any differences; (3) suggestions for improving the lab.

The Conclusion of my lab report…

- ☐ directly states what I have learned about the scientific concept of the lab from doing the experimental procedure.
- ☐ gives enough details of what I have learned to be convincing.
- ☐ describes anything else I may have learned from doing the lab and writing the report (something about the lab procedure, methods of analyzing data, etc.).

The References for my lab report…

- ☐ includes all the sources I have used in writing my lab report, such as the lab manual, the textbook, and any reference books or articles I cited.
- ☐ uses the appropriate documentation style for citations and references (CBE, ACS, etc.)

Overall issues: My lab report...

- ☐ uses the correct format (titles, captions, etc.) for the tables, graphs, and drawings
- ☐ is written in a scientific style (tone should be objective; sentences should be clear and to the point).
- ☐ is clear of spelling errors (used the spell check on my computer).
- ☐ includes all the necessary headings (each section of the report should have a heading).

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Evaluation Guide

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LabCheck: ***Evaluation Guide*** **Writer:**___________________

	F	D	C	B	A
Title					
• describes lab content concisely, adequately, appropriately					
Abstract					
• conveys a sense of the full report concisely and effectively					
Introduction					
• successfully establishes the scientific concept of the lab					
• effectively presents the objectives and purpose of the report					
• states hypothesis and provides logical reasoning for it					
Methods					
• gives enough details to allow for replication of procedure					
Results					
• opens with effective statement of overall findings					
• presents visuals clearly and accurately					
• presents verbal findings clearly and with sufficient support					
• successfully integrates verbal and visual representations					
Discussion					
• opens with effective statement of support of hypothesis					
• backs up statement with reference to appropriate findings					
• provides sufficient and logical explanation for the statement					
• sufficiently addresses other issues pertinent to lab					
Conclusion					
• convincingly describes what has been learned in the lab					
Presentation					
• citations and references adhere to proper format					
• format of tables and figures is correct					
• report is written in scientific style: clear and to the point					
• grammar and spelling are correct					
Overall Aims of the Report: *The student...*					
• has successfully learned what the lab is designed to teach					
• demonstrates clear and thoughtful scientific inquiry					
• accurately measures and analyzes data for lab findings					

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LabWrite Resources

Graphing Resources

Excel Tutorial

A step-by-step tutorial on how to use Excel. It covers both basic techniques (entering raw data, formula entry, cell displays, basic graphing) and advanced techniques (such as importing raw data, creating various kinds of graphs, culling data, formatting graphs, and using descriptive statistics in graphs--error bars).

Data Types

A flow chart to use for help when trying to categorize the types of data collected during the lab.

Tables vs. Graphs

A guide with helpful hints on how to decide which format best represents the data collected in lab.

Designing Tables

General information on creating tables to represent data collected in lab.

Graph Types

A flow chart to use when trying to decide which type of graph best represents the type of data collected in lab.

Bar Graphs

Use this guide for a description of the different types of bar graphs followed with examples that illustrate when to use each one.

Histograms

Use this guide for a description of the different types of histograms followed with examples that illustrate when to use each one.

Line Graphs

Use this guide for a description of the different types of line graphs followed with examples that illustrate when to use each one.

Scatter Plots

Use this guide for a description of the different types of scatter plots followed with examples that illustrate when to use each one.

Revising Your Visuals

A useful guide that provides helpful hints on how to refine and modify key elements of visuals to prepare them for final presentation.

Error Bars

Provides information on summarizing data with mean values and representing experimental uncertainty with error bars.

Representing Significant Digits

This page will give you some guidance on how to report your experimental results with the appropriate number of significant digits.

Writing Resources

Quick Guide to PostLab Stages

An abbreviated version of the Post-Lab stages to be used as a quick reference guide by those already familiar with Post-Lab.

LabChecklists

A checklist of the elements that need to be in an effective lab report is available for any type of lab you may have completed--standard, descriptive, or designed by you. The LabChecklist follows the guidelines presented in PostLab and is designed for use prior to turning in the lab report for a grade. Use this to double-check the lab report in order to improve the chances of getting a better grade.

Help Improving Your Lab Report Grade

Helpful hints on how to improve each component of the lab report for any type of lab you may have completed--standard, descriptive, or designed by you. Use this in conjunction with the LabCheck Evaluation Guides available for each type of lab for help in interpreting and improving lab report grades. Before using this resource, make sure you are familiar with PostLab.

LabCheck Evaluation Guides

A LabWrite Evaluation Guide is available for any type of lab you may have completed--standard, descriptive, or designed by you. The Evaluation Guide lists criteria that instructors will be using to grade your lab reports. Links to Help Improving Your Lab Report Grade are available within each section of the guide. Use this guide to become familiar with the LabWrite grading criteria before turning in your lab report and to help you interpret your lab report grade after you get it back.

Online Writing Handbook

Web sites to help you with questions about grammar, style, punctuation, mechanics, using the internet, search engines, and much more.

Citations and References

Documenting sources : advice on citing information from outside sources in the body of the report and listing those sources of information in the References section at the end of the report.

Additional Resources

Writing a Research Proposal

A step-by-step guide that takes you through the process of writing a research proposal.

Labwrite for Middle School

Labwrite activities for students in the middle grades.

Sample Lab Reports

Examples of lab reports that illustrate how the parts of the report are written and arranged. Use this to see what a completed lab report looks like.

Glossary

An alphabetical list of words and phrases with their definitions as used throughout LabWrite.

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